500, 201

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
24 July 2003 (24.07.2003)

PCT

(10) International Publication Number
WO 03/061163 A1

(51) International Patent Classification[7]: H04B 10/18

(21) International Application Number: PCT/EP02/00357

(22) International Filing Date: 16 January 2002 (16.01.2002)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: **AGILENT TECHNOLOGIES, INC.** [US/US]; 395 Page Mill Road, Palo Alto, CA 94306 (US).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **BELLER, Josef** [DE/DE]; Hegelstrasse 11, 72074 Tuebingen (DE).

(74) Agent: **BARTH, Daniel**; Agilent Technologies Deutschland GmbH, Patentabteilung, Herrenbergerstrasse 130, 71034 Boeblingen (DE).

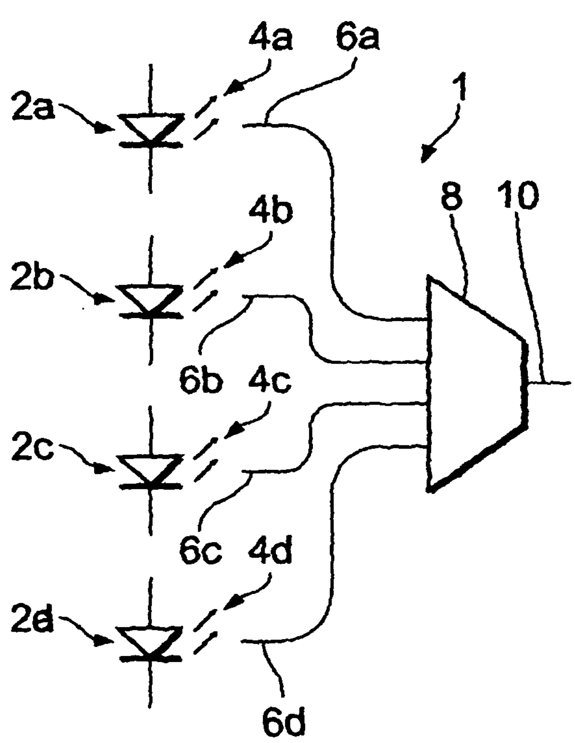
(81) Designated States *(national)*: JP, US.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: A METHOD AND APPARATUS FOR CONTROLLING OPTICAL SIGNAL POWER



(57) Abstract: The present invention relates to a method of increasing the power of an optical signal to be provided to an optical component (10), e.g. an optical fiber, until non-linear effects in the optical component (10) occur, at most, preferably by using at least two initial optical signals (4a, 4b, 4c, 4d) to create the optical signal, the initial optical signals (4a, 4b, 4c, 4d) having different center wavelengths (λ) and being preferably combined with each other to create the optical signal.

WO 03/061163 A1

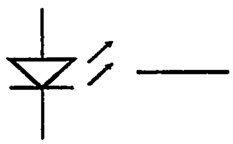


Fig. 1a

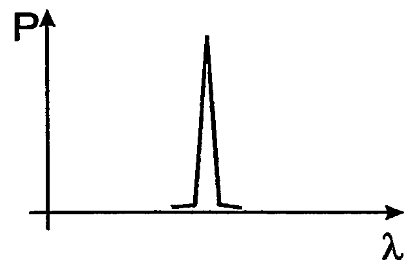


Fig. 1b

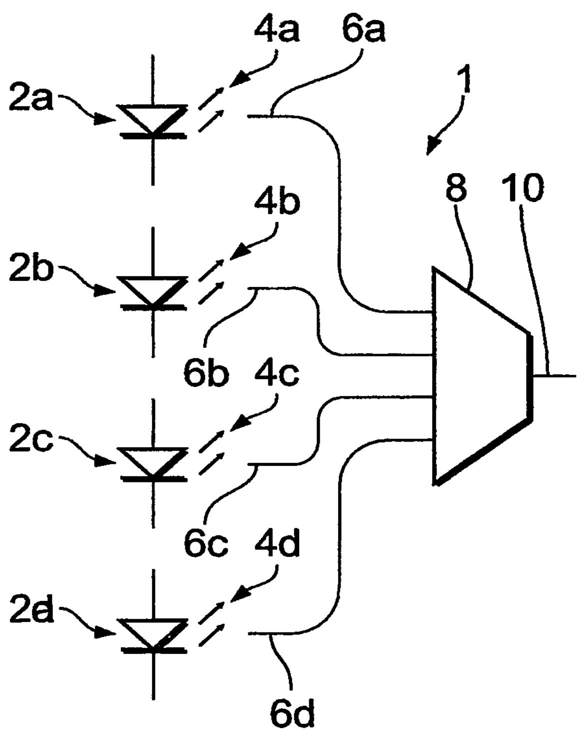


Fig. 2a

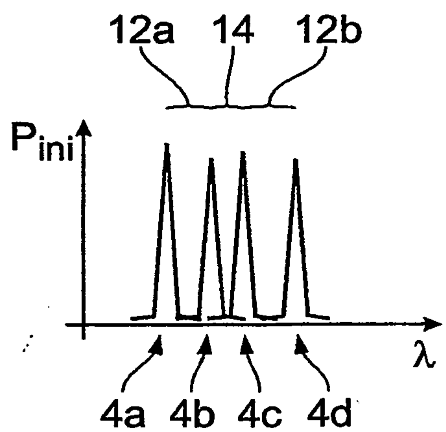


Fig. 2b

A METHOD AND APPARATUS FOR CONTROLLING OPTICAL SIGNAL POWER

BACKGROUND OF THE INVENTION

The present invention relates to increasing the power of an optical signal.

When performing optical measurement methods or using optical measurement equipment, e.g. OTDRs, high power probing signals are desirable since the response signals from a device under test are proportional to the level of the stimulus signal. However, if the device under test is for example a fiber, then it is possible that non-linear effects in the fiber limit the maximum power level of the optical probing signals depending on fiber and signal properties. Such adverse effects of high power levels of the optical probing signal can be 4-wave mixing, cross-modulation, Raman scattering, or Brillouin scattering.

A state-of-the-art light source used in optical test equipment is for example a semi-conductor laser diode which exhibits a narrow optical spectrum. The demand for higher optical power can't be simply satisfied with a stronger laser diode because such a device is most likely not available if one is already working with high powered devices and because non-linear effects in fibers start to arise.

SUMMARY OF THE INVENTION

Therefore, it is an object of the invention to provide improved intensification of an optical signal power.

The object is solved by the independent claims.

In the context of the present invention the term relevant non-linear effects can be defined, e.g. as the loss of the optical power to frequencies newly generated by the non-linear effects.

An advantage of the present invention is the possibility to use high-power probing signals having a higher maximum power level without showing non-

linear effects, compared to the high-power probing signals known from the prior art. This possibility is enabled by the present invention since the invention increases the maximum power level of an optical probing signal by broadening the spectral density of the signal. The amount of the broadening, i.e. the spectral distribution and spectral width of the probing signal that can be tolerated depends on the type of measurement the probing signals are used for.

In a preferred embodiment of the invention the broadening of the spectral density of the optical signal is performed by using at least two initial optical signals to create the optical signal, the initial optical signals having different center wavelengths. This embodiment implements the invention in an easy way. In the respective apparatus of the invention it is preferred to combine two or more laser diodes with a preferably low-loss combiner to produce a high-power output signal with a spectral distribution that can be preferably set by proper selection of the laser diodes. The individual laser diodes have preferably approximately the same optical power. More preferably, the spacing of the center wavelengths of each laser diode is not equal between at least two of the center wavelengths.

In order to enhance the effect of the inventive method it is preferred to use five to ten laser diodes within a total spectral width of approximately 5 to 20 nanometers. This can preferably be done by using an N-port combiner which preferably shows coupling efficiencies C that are greater than 1/N and are preferably as close as possible to 1. When using such a combiner the total output power increases considerably and the total output P_{tot} can reach $P_{tot} = N \times P_0 \times C$.

Other preferred embodiments are shown by the dependent claims.

It is clear that the invention can be partly embodied or supported by one or more suitable software programs, which can be stored on or otherwise provided by any kind of data carrier, and which might be executed in or by any suitable

data processing unit.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and many of the attendant advantages of the present invention will be readily appreciated and become better understood by reference to the following detailed description when considering in connection with the accompanied drawings. The components in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present invention. Features that are substantially or functionally equal or similar will be referred to with the same reference sign(s).

Fig. 1a shows an example of a laser diode of the prior art together with a optical fiber connected to the laser diode;

Fig. 1b shows an optical spectrum emitted by the laser diode of Fig. 1a;

Fig. 2a laser diodes combined according to an embodiment of the present invention; and

Fig. 2b shows a combined spectrum generated by the laser diodes of Fig. 2a.

DETAILED DESCRIPTION OF THE INVENTION

Referring now in greater detail to the drawings, Fig. 2a shows a schematic illustration of an embodiment 1 of an apparatus according to the present invention. Embodiment 1 comprises as laser sources four laser diodes 2a, 2b, 2c and 2d. The laser diodes 2a, 2b, 2c,2d emit initial optical signals 4a, 4b, 4c, 4d, respectively, into four optical fibers 6a, 6b, 6c, 6d, respectively. All laser diodes 2a, 2b, 2c, 2d emit approximately the same optical power.

The four initial optical signals 4a, 4b, 4c, 4d in the optical fiber 6a, 6b, 6c, 6d are combined with the help of a low-loss combiner 8 to an optical signal 10.. Combining the four laser diodes 2a, 2b, 2c, 2d with the combiner 8 produces

the optical signal 10 with a high output power and with a spectral distribution that can be set by selection of the center wavelength of the initial optical signals 4a, 4b, 4c, 4d of the laser diodes 2a, 2b, 2c, 2d.

As shown in Fig. 2b all initial optical signals 4a, 4b, 4c, 4d have approximately the same initial optical power P_{ini} . However, the spacing 12a between the center wavelength λ of the initial optical signals 4a and 4b preferably is not the same as the spacing 12b between the center wavelength λ of the initial optical signals 4c and 4d and is different, e.g. bigger than the spacing 14 between the center wavelength λ of the initial optical signals 4b and 4c.

The 4-port combiner 8 shows a coupling efficiency C that is greater than 1 / 4 and is close to 1. The total output power P_{tot} can be calculated as follows: $P_{tot} = 4 \times P_0 \times C$, P_0 being the power of a single laser diode 2a, 2b, 2c, 2d, assuming all diodes 2a, 2b, 2c, 2d emit the same optical power. With a proper selection of the wavelength λ of the individual laser diode 2a, 2b, 2c, 2d, the resulting spectrum according to Fig. 2b can minimize non-linear effects in the optical fiber 10 yielding a much higher response signal in an optical measurement, e.g. an OTDR measurement, and thus a gain in a signal to noise ratio, in measurement speed, or in measurement accuracy etc. In embodiment 1 the added spacings 12a, 14 and 12b between the center wavelength of initial optical signal 4a and initial optical signal 4d amount to approximately 5nm. In embodiment 1 the center wavelengths of the initial optical signals 4a, 4b, 4c, 4d have been chosen to be 1310 nm, 1312 nm, 1313 nm, 1315 nm, respectively.

CLAIMS:

1. A method of increasing the power of an optical signal to be provided to an optical component (10), comprising the step of:

   broadening the spectral density of the optical signal until relevant non-linear effects in the optical component (10) occur, at most.

2. The method of claim 1, further comprising the steps of:

   broadening the spectral density of the optical signal by using at least two initial optical signals (4a, 4b, 4c, 4d) to create the optical signal, the initial optical signals (4a, 4b, 4c, 4d) having different center wavelengths (λ).

3. The method of the claims 1 or 2, further comprising the steps of:

   using 4 to 11 initial optical signals (4a, 4b, 4c, 4d), preferably 5 to 10 initial optical signals (4a, 4b, 4c, 4d).

4. The method of any one of the claims 1 - 3, further comprising the steps of:

   creating the optical signal by combining the initial optical signals (4a, 4b, 4c, 4d) to the optical signal.

5. The method of any one of the claims 1-4, further comprising the steps of:

   adjusting a spacing (12a, 12b, 14) between the center wavelengths (λ) of any two of the initial optical signals (4a, 4b, 4c, 4d) to be not equal to each other.

6. The method of any one of the claims 1-5, further comprising the steps of:

   adjusting the initial optical signals (4a, 4b, 4c, 4d) to have approximately the same optical power (P_{ini}).

7. The method of any one of the claims 1-6, further comprising the steps of:

increasing the power of the optical signal until relevant non-linear effects in the optical component (10) occur, at most, by increasing the power (P_{ini}) of the initial optical signals (4a, 4b, 4c, 4d) until relevant non-linear effects in the optical component (10) occur, at most.

8. The method of any one of the claims 1-7, further comprising the steps of:

adjusting the spacing (12a, 12b, 14) between the center wavelength (λ) of the initial optical signal (4a) having the smallest center wavelength (λ) and the initial optical signal (4d) having the biggest center wavelength (λ) to be 20 nanometer, at most.

9. The method of any one of the claims 1-8, further comprising the steps of:

combining the initial optical signals (4a, 4b, 4c, 4d) by coupling them together, the coupling having coupling efficiencies C > 1/N, preferably approximately 1, if $P_{tot} = N \times P_{ini} \times C$, P_{tot} being the total output of the combined initial optical signals (4a, 4b, 4c, 4d), P_{ini} being the output of a single initial optical signal (4a, 4b, 4c, 4d), N being the number of the initial optical signals (4a, 4b, 4c, 4d).

10. A software program or product, preferably stored on a data carrier, for executing the method of one of the claims 1 to 9 when run on a data processing system such as a computer.

11. An apparatus for increasing the power of an optical signal to be provided to an optical component (10), until relevant non-linear effects in the optical component (10) occur, at most comprising:

a broadening device (2a, 2b, 2c, 2d, 6a, 6b, 6c, 6d, 8) for broadening the spectral density of the optical signal.

12. The apparatus of claim 11, further comprising:

at least two laser sources (2a, 2b, 2c, 2d) to provide at least two initial

optical signals (4a, 4b, 4c, 4d) to create the optical signal, the initial optical signals (4a, 4b, 4c, 4d) having different center wavelengths (λ).

13. The apparatus of the claims 11 or 12, further comprising:

at least one combiner (8) to combine the initial optical signals (4a, 4b, 4c, 4d) to the optical signal.

14. The apparatus of any one of the claims 11 - 13, further comprising:

the combiner (8) having coupling efficiencies C > 1/N, preferably approximately 1, if $P_{tot} = N \times P_{ini} \times C$, P_{tot} being the total output of the combined initial optical signals (4a, 4b, 4c, 4d), P_{ini} being the output of a single initial optical signal (4a, 4b, 4c, 4d), N being the number of the initial optical signals (4a, 4b, 4c, 4d).

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 02/00357

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B10/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 359 684 A (SIEMENS AG) 29 August 2001 (2001-08-29) page 3, line 11 - line 23 page 5, line 19 - line 30 page 6, line 33 -page 7, line 7 claim 1 figure 1 ---	1-14
A	EP 0 767 395 A (CSELT CENTRO STUDI LAB TELECOM) 9 April 1997 (1997-04-09) abstract column 3, line 55 -column 4, line 14 column 6, line 35 - line 54 claims 1,4 -----	1-14

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 September 2002	19/09/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Reville, L

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 02/00357

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
GB 2359684	A	29-08-2001	DE	10049394 A1	31-05-2001
EP 0767395	A	09-04-1997	IT	TO950782 A1	02-04-1997
			CA	2186819 A1	03-04-1997
			DE	767395 T1	12-11-1998
			EP	0767395 A2	09-04-1997
			JP	2858400 B2	17-02-1999
			JP	9127563 A	16-05-1997
			US	5754334 A	19-05-1998